Design project discussion

Aerospace Systems \triangleright ENGN4339 \triangleright Week 2

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- Requirements, guidelines and assessment criteria are provided in the *Wattle* document.
- We will go through the technical background of this project.
- We will further discuss particular sections of the project that might be challenging.

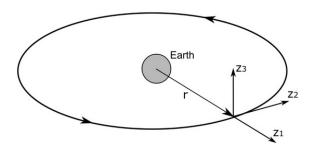
We briefly discussed about docking from a technical standards perspective in Lecture 1B.

From a functionality perspective:

- Docking: Proximity maneuver and attachment to the ISS.
 - ▶ Dragon, Soyuz, Progress, Space Shuttle
- Berthing: Capture and attachment to ISS by a robotic arm.
 - ▷ Cygnus, HTV, Dragon, ATV

Space rendezvous

Understanding the Clohessy-Wiltshire frame of reference.



*Image License: CC BY 4.0, Credit: M. Boggio, L. Colangelo, M. Virdis, M. Pagone, and C. Novara, "Earth Gravity In-Orbit Sensing: MPC Formation Control Based on a Novel Constellation Model," Remote Sensing, vol. 14, no. 12, p. 2815, Jun. 2022. Link: doi: 10.3390/s14122815.

Performance index

On the performance index.

- The integral.
- The inner product.

$$J = \frac{1}{2} \int_{t_i}^{t_f} U^T U \, dt$$

Consider an initial value problem.

$$\dot{y} = f(y, t), \ y(t_0) = y_0$$

Solution by classic Runge-Kutta method.

$$y_{n+1} = y_n + \frac{h}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

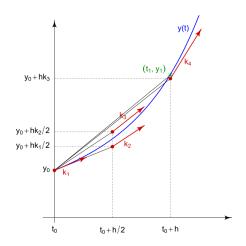
$$k_1 = f(t_n, y_n)$$

$$k_2 = f(t_n + \frac{h}{2}, y_n + h\frac{k_1}{2})$$

$$k_3 = f(t_n + \frac{h}{2}, y_n + h\frac{k_2}{2})$$

$$k_4 = f(t_n + h, y_n + hk_3)$$

Numerical propagation



^{*}Image License: CC BY-SA 4.0, Credit: HilberTraum. Link: https://commons.wikimedia.org/wiki/File:Runge-Kutta_slopes.svg

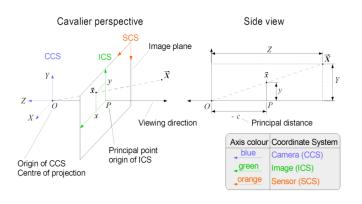
Numerical propagation

State-space representation.

$$\dot{x} = Ax + Bu$$
, $x(t_0) = x_0$

How do we represent our design problem in this format?

How to model a pinhole camera?



^{*}Image License: CC BY-SA 4.0, Credit: Olaf Peters. Link: https://commons.wikimedia.org/wiki/File:Central_Projection_Idealised_Camera_Model.png

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[Image\ coordinates] = [Intrinsic\ matrix] \times [Extrinsic\ matrix] \times [World\ coordinates]
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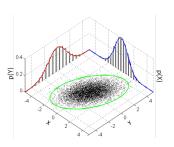
- World coordinates: Position of the ISS in CW frame.
- Extrinsic matrix: Transforms ISS to camera coordinate frame.
- Intrinsic matrix: **Projects** image using camera parameters.

Measurements

How do we simulate noisy sensor measurements?

Measured value = True value + Sensor noise

Sensor noise \rightarrow Sample a Gaussian distribution of mean 0 and variance σ^2 .



^{*}Image: License: CC0 1.0 Universal Public Domain Dedication. Link: https://commons.wikimedia.org/wiki/File:MultivariateNormal.png